

(12) **UK Patent Application** (19) **GB** (11) **2 360 922** (13) **A**

(43) Date of A Publication 03.10.2001

(21) Application No 0007735.4

(22) Date of Filing 31.03.2000

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(51) INT CL⁷

H05B 3/34, A61B 18/04 // A47C 27/00, A47G 9/02

(52) UK CL (Edition S)

H5H HAA3 HAF5 HBA2 H104 H110 H126 H170 H198
 H224 H230 H233 H234 H240 H273 H274
 U1S S1027 S1213 S1216

(56) Documents Cited

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(58) Field of Search

UK CL (Edition R) H5H HAAX1 HAA2 HAA3 HAA7
 HAA8 HAA9 HBA2
 INT CL⁷ H05B 3/34 3/36 3/38
 ONLINE:WPI,JAPIO,EPODOC

(54) Abstract Title

A heating device for surface heating of a patient's body

(57) The heating element comprises a first conductor 18a made of a relatively high specific resistivity material as compared to the second conductor 18b, the second conductor facing the body in use, being made of a material with high heat conductivity. The first conductor thus serves as a heater and the second conductor as a heat diffuser which also may comprise the return conductor. The heating element 25 comprises a bed sheet 19 or mattress incorporating the conductors and the device includes control means 26-28 and low voltage power source either from mains transformer 22 or batteries B1, B2 via switch 25.

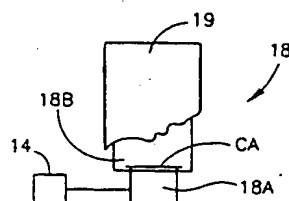


FIG. 2B

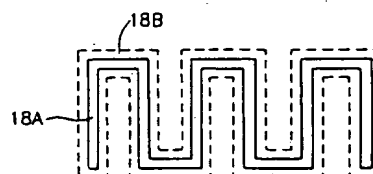


FIG. 3

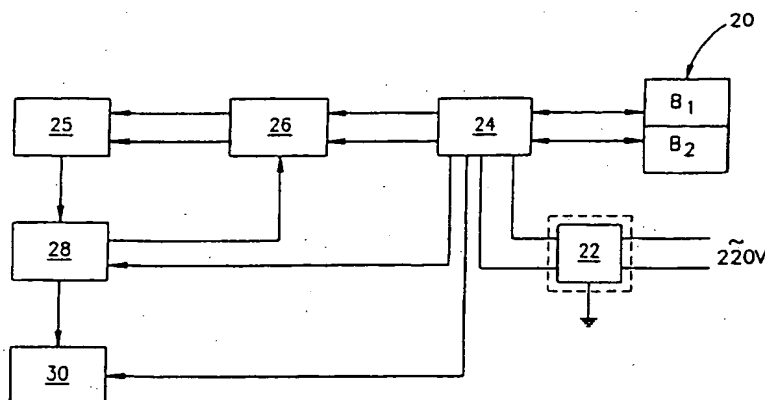


FIG. 4

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

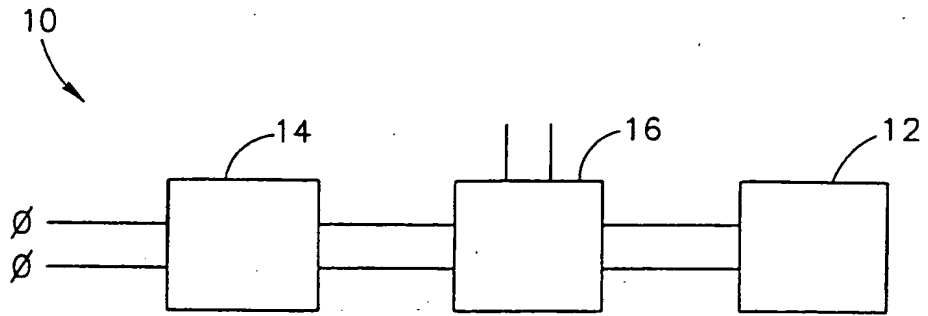


FIG.1

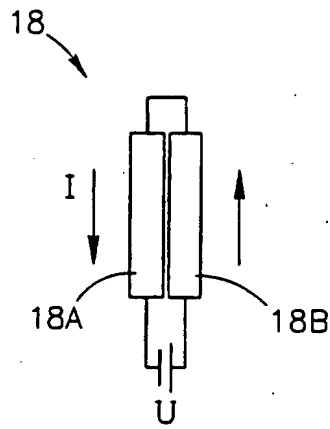


FIG.2A

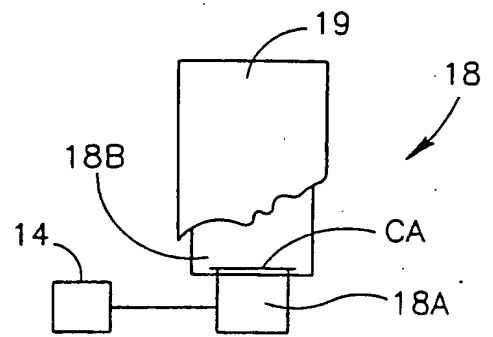


FIG.2B

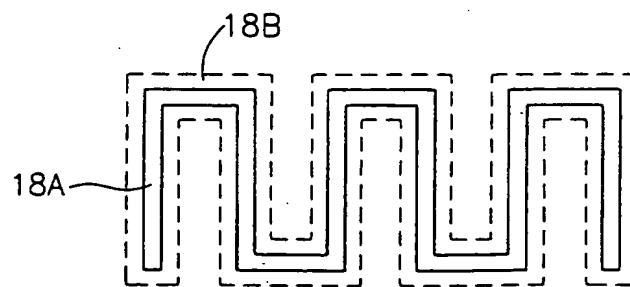


FIG.3

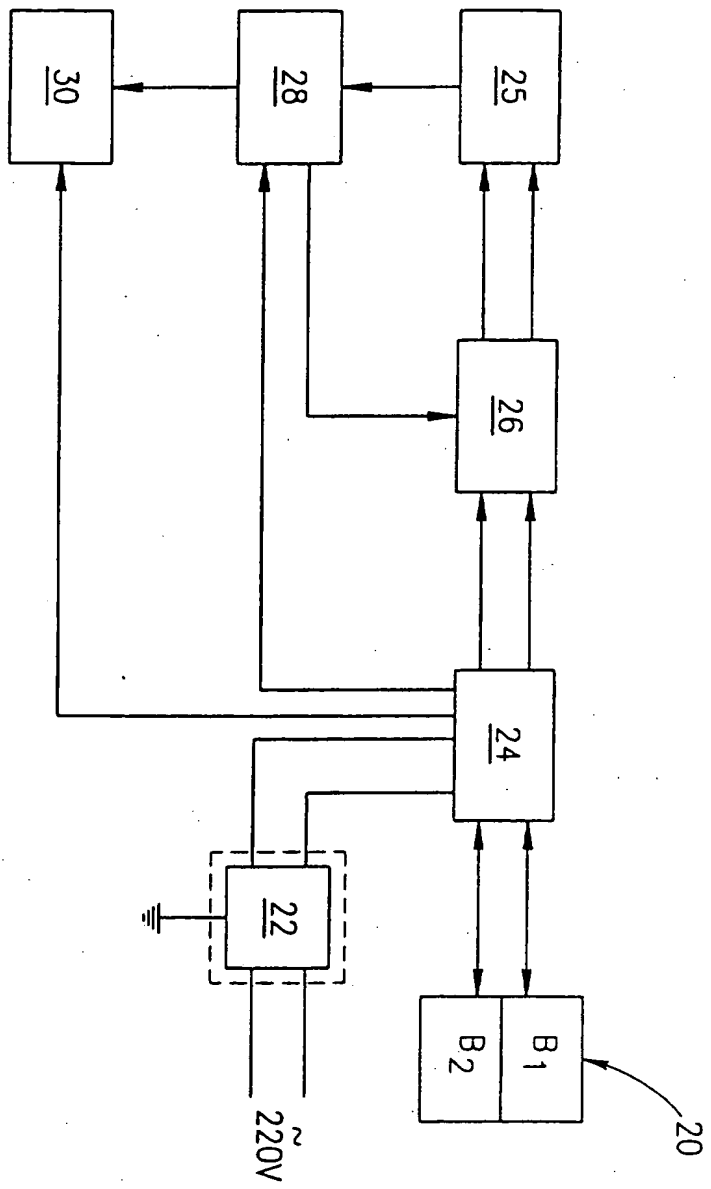


FIG. 4

A Heating Device for Heating a Patient's Body

FIELD OF THE INVENTION

The present invention is generally in the field of heating techniques, and relates to a heating device for surface heating of a body. The invention is particularly useful for heating a patient's body during surgical procedures and major
5 operations.

BACKGROUND OF THE INVENTION

During a surgical procedure and within a certain time period thereafter, a patient's body requires to be externally heated. Heat transfer devices for transferring heat to the patient's body, which are used at present in operating rooms, are
10 generally of two types: the first type utilizes a closed circuit with heated water circulating thereinside, and the second utilizes an open circuit, wherein heated air blows around the patient's body.

The heating technique of the first kind involves placing a thin rubber mattress underneath the patient. Warm water circulates through this mattress. A
15 device, equipped with a heat exchanger and pump, warms and circulates the water. Some of these devices also have the capability of regulating the temperature of the water based on body temperature measured with a rectal probe. The heat exchange characteristics of the heating mattress are unsatisfactory since only the patient's back is warmed. It is used mainly in situations where it is impossible to place
20 anything on the front surface of the patient's body. It is not as effective as a convection warm air system in maintaining body temperature intraoperatively.

As for the technique of the second type, it is carried out by a system consisting of a modified "hair dryer" that supplies warm air to specifically designed blankets. The blankets facilitate the distribution of the warm air over the non-operative portion of the patient's body. This system is capable of providing excellent heat transfer to a patient, and is used both to prevent the development of hypothermia and to warm hypothermic patients. The device can provide warm air at 37-42°C. The footprint of the device is small, and there is a pole mounted version. This device does not make much noise and is extremely easy to use.

Intraoperative warming is needed during most operative procedures lasting longer than 30 minutes, and in all operations on children weighing less than 15 kilograms. The only situation where warming is practically not needed, are short procedures (less than 30 minutes), and when the temperature of the patient's body is intentionally lowered. Most patients begin losing body heat either prior to anesthesia or immediately upon the induction of anesthesia. Much body heat is lost within an hour of the start of anesthesia. Therefore, warming must begin either before or immediately following the induction of anesthesia.

One of the problems of intraoperative warming is associated with the requirements for servo-controlled delivery of heat, aimed at preventing overheating and allowing for the increased delivery of warmth to patients who are continuously losing body heat. Another problem is associated with the need for the circumferential warming of limbs, warming of discontinuous areas of the body and the possibility of warming sterile areas of the operative field. It is desirable to place a heating device on individual parts of the patient's body, not underneath, so as to prevent the further loss of heat. Additionally, it is desirable to prevent the fan distribution of the warm air, and, while warming the desired parts of the patient's body, to prevent the warming of surgeons, nurses and anesthesiologists presented at the time.

Notwithstanding the fact that electrical heating has evident advantages such as the possibility of the continuous control of heating, including computer control and automatic management, electrical heating devices have never been used for

intraoperative warming to maintain the required temperature of a patient's body. This is due to the fact that the use of electrical heating in operating rooms needs to guarantee the following three complex tasks:

1. It should guarantee electrical safety, namely, to completely stave off
5 the damage of the electrical voltage, especially taking into account that the patient is undressed, various solutions are in use during an operation, and the presence of various metal instruments, as well as hemorrhage.

2. It should guarantee to avert the danger of burns that could be caused by the local overheating of heating elements.

10 3. It should guarantee the absence of the influence of electromagnetic effects on electronic equipment involved in the operation or located in the vicinity of the heating device.

It is important to understand that in most cases, the above three tasks have to be accomplished together and completely. For example, to avoid the damage of
15 electrical voltage, voltages as low as possible must be used. However, the use of low voltages with the required power compels the operation to take place with a high current, while this increase in current affects the electronics located in the vicinity of the heating device.

To decrease to zero the influence of the electromagnetic field of an electric
20 power source onto the functioning electronics, it is known to utilize a bifilar arrangement of conductors. This technique is disclosed for example, in the patent document DE29610436. However, this technique unavoidably leads to local heating, owing to the fact that the conductors in which heat required for heating an object (e.g., a patient's body) is dissipated, are located very close to each other.

25 The use of bifilars is generally known as directed towards decreasing the level of the electromagnetic field. Bifilars therefore are widely used in domestic interior electric wiring, in field-effect electrical engineering, as well as in machines for contact welding where the current reaches the values of 10.000A.

As defined by accepted standards with respect to this specific application of
30 maintaining the temperature of a patient's body, to completely avoid the damage of

burns to a patient's body, the temperature on a heating element itself, mainly on its external surface, should not exceed 41°C . At the same time, the surface temperature of the patient's body should be maintained at a level of 37°C . Accordingly, the heat flow from the heating element to the patient's body should be carried out with the maximum temperature gradient of 4°C . Taking into account that several layers of materials with very low heat conductivity (air, tissue, polyethylene) have to be accommodated between the heat dissipating element and the body, the exclusive complication of this problem is evident.

SUMMARY OF THE INVENTION

There is accordingly a need in the art to facilitate the technique of surface heating a body, by providing a novel heating device and a heating system utilizing the same.

It is a major feature of the present invention to provide such a heating device which is capable of active heat diffusion carried out by a heating element itself, thereby enabling to obtain an as low as desired temperature gradient between the temperature of the heating element and the surface temperature of a heated body. The need for a heat diffuser is associated with the fact that in order to avoid local heating which could lead to burns, the surface through which heat is transferred to the body should be substantially equal to the surface area of the body segments to be heated. The operation of the heating element is mainly aimed at decreasing a specific heat flow that reaches the surface of the patient's body.

The main idea of the present invention consists of designing a heating element from two conductors having relatively lower and relatively higher specific resistivity, when compared to each other. The conductor having higher specific resistivity serves as a heating conductor, while the other conductor having lower specific resistivity is characterized by high heat conductivity and faces the body to be heated, when in the operation of the device. This conductor with relatively low resistivity and high heat conductivity serves as a heat diffuser, and is accommodated between the heating conductor and the body to be heated. The heat

diffuser has an external surface larger than that of the heating conductor, preferably no less than 5 times larger. Due to the high heat conductivity of this conductor, heat dissipated by the heating conductor is uniformly distributed and transferred to the body to be heated with an acceptable density of the heat flow, namely such as to
5 prevent overheating of the body.

With regard to the above indicated application of maintaining the temperature of the patient's body at 37°C when in an operating room, it has been found by the inventor that, due to the provision of a heat diffuser, it is possible to reduce the temperature of the external surface of the heating conductor at 3-4°C,
10 while maintaining the required temperature of the surface of the patient's body.

The heating device, according to the invention, actually presents a heater with an active diffuser. When using an accumulator as a common power source for both the heating conductor and the heat diffuser conductor, it appears to be sufficient to connect the heat diffuser conductor in series with the heating
15 conductor to completely solve the problem of the influence of the heating element onto the electronics located in its vicinity. Generally, however, each of these conductors can be associated with its own power source, preferably an accumulator.

The diffuser conductor is not necessarily connected to a power source. For example, in those cases when the compensation for an electromagnetic field created
20 by the passage of electric current through the heating conductor is not required, the heat diffuser conductor need not be connected to the power source.

It should be noted that the heating element may be composed of three conductors, including a heating conductor and two heat diffuser conductors. One of the heat diffuser conductors ("passive" diffuser), which faces the object to be
25 heated during the operation of the device, is not connected to the power source, and may, for example, be located inside a bed sheet. This "passive" heat diffuser is in good thermal contact with the other heat diffuser conductor ("active" diffuser), which is connected to the power source, and is in good electric insulation from the "active" heat diffuser. The heating conductor and the "active" heat diffuser
30 conductor are accommodated and connected to the power source in a manner to

provide compensation of the electro-magnetic fields produced by the passage of electric currents therethrough. Each of the conductors (bands) is covered by a thin insulating layer, e.g., lacquer.

The heat diffuser conductor with high heat conductivity carries out three
5 functions: (1) it reduces the density of the heat flow that reaches the surface of the body to be heated; (2) provides uniform heat transfer to the surface area to be heated; and (3) enables complete compensation of a magnetic field created by an electric current passing through the heating strip. provided the electric currents flow in these conductors in the opposite directions.

10 An accumulator, when used in the heating device of the present invention, also performs two important functions: first, it provides a direct current supply source of low voltage without the need for grounding, and has no alternating component (thereby turning the task of avoiding the influence onto the electronics located in the vicinity of the heating device into the task of compensating for a
15 magnetic field created by the electric current flowing through the heating conductor); second, it presents not only a power supply source of low, safe voltage, but safety is even guaranteed in any accidental situation arising, since when being connected to the heating device, the accumulator is previously disconnected from the power network by a mechanical switch.

20 The application of heating a patient's body actually presents surface heating for maintaining the surface temperature of a heated body.

There is thus provided according to one aspect of the present invention, a heating device for surface heating of a body so as to maintain a required temperature of the body. the heating device comprising an electrical heating
25 element and a power source for supplying a required voltage to the heating element. wherein:

said heating element comprises first and second conductors made of materials with relatively high and low specific resistivities. respectively. as compared to each other. the second conductor material having high heat conductivity:

the second conductor is accommodated between the first conductor and the body when in an operative position of the heating device, and at least said first conductor with relatively high specific resistivity is connected to said power source during the operation of the device. such that the first conductor is a heater and the second conductor is a heat diffuser, thereby providing as low as desired temperature gradient between the surface temperature of the heating conductor and said required temperature of the body.

The surface area of the second conductor is larger than the surface area of the first conductor. Generally, the surface area of the second conductor substantially corresponds to the surface area of the body to be heated.

Preferably, each of the first and second conductors is a strip. The first conducting strip is designed such that its physical parameters (length l , width b , thickness δ and specific resistivity ρ) are connected to electrical parameters of the power source directly coupled to the heating element in accordance with the following relationships:

$$l \geq k \cdot U \cdot \sqrt{\frac{\delta}{\rho}}$$

$$b \geq k \cdot I \cdot \sqrt{\frac{\rho}{\delta}}$$

Here, U is the voltage that falls on the first conductor: I is the current flowing through the conductor: k is a coefficient depending on the body to be heated and said required temperature. so as to satisfy the condition that electric power supplied to the conductor is substantially equal with a heat power dissipated through the surface of the conductor.

The above approach for designing a heating strip aimed at providing an as low as desired temperature gradient between the temperature of the surface of the

heating strip and the required temperature of the body is developed by the inventor of the present application and disclosed in WO 97/09866. The main idea of this technique consists of considering the relationship between the physical parameters (i.e., length, width, thickness and specific resistivity) of the heating strip, and its
5 electrical parameters (i.e., voltage and current). The physical parameters are dictated by the heating power W required for heating a specific object to a desired temperature, that is $W=kS$, where S is the area of the outer surface of the heating strip through which the heating power W is dissipated (i.e., product of the length l and width b of the outer surface), and k is the coefficient depending on the object to
10 be heated and the desired temperature. The electrical parameters are dictated by electric power, W' , supplied to the heating strip by a power source, that is $W'=UI$, wherein U is the electric potential and I is the electric current passing through the heating strip, which depends on the specific resistivity ρ of the selected electric conductive material. To facilitate the understanding of this idea, let us assume that
15 the temperature gradient needs to be reduced. For this purpose, the value of k is appropriately increased, which automatically causes the surface area S of the heating element to be increased. This, in turn, means that lower voltages should be supplied to the heating element, and this factor is used in selecting the electric conductive material with an appropriate specific resistivity.

20 Preferably, the first and second materials are selected such that their specific resistivities are, respectively, in the ranges $0.3-1\text{Ohm}\cdot\text{mm}^2/\text{m}$ (e.g., transformer steel, stainless steel) and $0.015-0.03\text{Ohm}\cdot\text{mm}^2/\text{m}$ (e.g., aluminum foil, copper).

The first and second conductors may be arranged in a parallel spaced-apart relationship along their length, and may be electrically connected in series to each
25 other. Each of the first and second strips is preferably coated with a thin insulating layer, which may be lacquer.

Preferably, the required voltage to be supplied to the heating element is substantially low, e.g., up to 12V. To this end, the power source typically comprises a step-down transformer interconnected between the power network and the
30 heating element. The power source preferably also comprises an accumulator unit,

including at least two batteries, which are selectively operable by a switching unit, so as to connect a selective one of the batteries to the heating element. When one of the batteries is in operation, the other one may be charged with a charging unit.

The device according to the invention is particularly useful for heating a patient's body undergoing treatment, e.g., an operation in an operating room. In this case, the heating element is accommodated inside a bed-sheet for covering the body to be heated, or a mattress underneath the patient's body. The heating element may be formed of several separate parts for heating selective segments of the patient's body, such as legs and/or arms.

10 According to another aspect of the present invention, there is provided a heating device for surface heating of a patient's body in an operating room, the heating device comprising an electrical heating element and a power source coupled to the heating element for supplying a required voltage thereto, wherein

15 said heating element comprises first and second conductors made of materials with relatively high and low specific resistivities, respectively, as compared to each other, the second conductor material having high heat conductivity; the second conductor is accommodated between the first conductor and the body when in an operative position of the heating device, and at least said first conductor with relatively high specific resistivity is connected to said power source during the operation of the device, such that the first conductor is a heater and the second conductor is a heat diffuser, thereby providing an as low as 20 desired temperature gradient between the surface temperature of the heating conductor and said required temperature of the body.

25 According to yet another aspect of the present invention, there is provided a heating system to be applied to a body for heating it up to a required temperature and maintaining this temperature, the system comprising a heating device, a power source for supplying a required voltage thereto, and a control system, wherein

30 the heating element comprises first and second conductors made of materials with relatively high and low specific resistivities, respectively, as compared to each other, the second conductor material having high heat conductivity;

the second conductor is accommodated between the first conductor and the body when in an operative position of the heating device, and at least said first conductor with relatively high specific resistivity is connected to said power source during the operation of the device, such that the first conductor is a heater
5 and the second conductor is a heat diffuser, thereby providing an as low as desired temperature gradient between the surface temperature of the heating conductor and said required temperature of the body; and
the control system comprises at least one temperature sensor associated with the body to be heated, a processing and managing unit, and an indication unit, such
10 as to provide continuous control of the temperature of the body and of the operation of the temperature sensor and to provide indication thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, a preferred embodiment will now be described, by way of non-limiting
15 example only, with reference to the accompanying drawings, in which:

Fig. 1 is a block diagram of the main constructional parts of a system according to the invention;

Figs. 2A and 2B more specifically illustrate two different examples, respectively, of the relative accommodation of first and second conductors of a
20 heating element and a power source, suitable to be used in the system of Fig. 1;

Fig. 3 illustrates an example of the implementation of the first and second conductors; and

Fig. 4 is a schematic illustration of main functional components of the system of Fig. 1.

25 DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring to Fig. 1, there is illustrated a heating system 10, according to the invention. The system 10 comprises such main constructional parts as a heating device 12 associated with a power supply source 14, and a control system 16.

The construction of the control system 16 does not form part of the present invention, and such a system may be of any known kind utilizing temperature sensors, processors, contact and non-contact switches, etc. As for the operation of the control system 16 aimed at the purposes of the present invention, it will be
5 described further below with reference to Fig. 3. The power supply source 14 as a separate element, is also known *per se*, and therefore its construction and operation need not be specifically described, except to note the following: the power supply source 14 is aimed at providing the normal operational mode of the heating device in accordance with instructions generated by the control system 16, as will be
10 described further below.

As shown in Fig. 2A and 2B, the heating device 12 is a heating element 18 composed of two conductors 18A and 18B. The conductors 18A and 18b are made of different materials possessing different physical properties: namely, that one of the conductors (18B in the present example), which, when in operation of the
15 device, is located between the other conductor (i.e., 18A) and the patient's body, is made of a conducting material having relatively low specific resistivity, as compared to that of the other conductor and has high heat conductivity.

For example, the conductor 18A has the specific resistivity in the range $0.3-1 \text{ Ohm} \cdot \text{mm}^2/\text{m}$ (e.g., transformer steel or stainless steel), and the conductor 18B
20 has the specific resistivity in the range $0.015-0.03 \text{ Ohm} \cdot \text{mm}^2/\text{m}$ (e.g., aluminum foil). As a result, the conductor 18A serves as a heating conductor, while the conductor 18B serves as a heat diffuser. Such a heating element is therefore capable of performing active heat diffusion.

In the example of Fig. 2A, the conductors 18A and 18B are electrically
25 connected in series with respect to the common power source 14, and are mounted in a spaced-apart parallel relationship along their entire lengths, close to each other. Such relative disposition of the conductors coupled to the common power source is similar to that of a bifilar, and therefore provides for compensation of magnetic fields created by the current passage through the conductors. It should, however, be

noted that the conductors **18A** and **18B** may be coupled to separate voltage supply elements of the power source (i.e., may be installed in separate electric circuits).

Generally, the conductors are mounted with respect to each other such as to provide good thermal contact between them. namely, there are substantially no heat losses within the contact area.

More specifically, the present invention is useful for maintaining the temperature of the patient's body while in an operating room, and is therefore described below with respect to this application. To this end, although not specifically shown, the entire heating element **18** may be accommodated inside a bed-sheet for covering the patient's body or inside a mattress.

According to the example of Fig. 2B, only the heat diffuser conductor **18B** is accommodated inside a bed-sheet **19**, and only the heating conductor **18A** is connected to the power source **14**. A thermal contact between the conductors is provided within a contact area **CA**. In this case, no electric current flows through the conductor **18B** during the operation of the heating device, and the conductor **18B** serves for uniformly distributing the heat dissipated through the surface of the heating conductor **18A** towards the surface area of the body to be heated (not shown), and for reducing the heat flow reaching the body.

Turning now to Fig. 3, there is shown that the conductors **18A** and **18B** are shaped like strips, and are in the present example accommodated in a spaced-apart, parallel relationship all along their lengths. The low specific resistivity, high heat conductivity strip **18B** has larger dimensions than that of the other strip **18A**, such that its surface area is no less than 5 times larger than that of the strip **18A**. The length and width of the heating strip **18A** satisfy the following relationships:

$$l \geq k \cdot U_{heat} \cdot \sqrt{\frac{\delta}{\rho}}$$

$$h \geq k \cdot I \cdot \sqrt{\frac{\rho}{\delta}}$$

Here, U_{heat} is the voltage that falls on the heating strip 18A (keeping in mind that the strips are connected in series); I is the current flowing through the entire circuit; ρ is the specific resistivity of the heating strip material; δ is the thickness of the heating strip; k is a coefficient depending on the body to be heated and the required temperature, selected so as to satisfy the condition that electric power supplied to the conductor is substantially equal to a heat power dissipated through the surface of the conductor.

It should be noted, although not specifically shown, that the heating element according to the invention may include an additional heating conductor. The two heating conductors are accommodated and electrically connected as exemplified in Fig. 2A, while the heat diffuser conductor is disconnected from the power source. This arrangement of two heating conductors will provide complete compensation of the electromagnetic fields produced by the electric current passage therethrough, while the heat diffuser conductor 18B will transfer the heat dissipated by these two conductors towards the body to be heated.

As indicated above, the heating element 18 is capable of performing active heat diffusion. The requirement for heat diffusion is associated with the following. Power required for maintaining the temperature of the patient's body (mainly the temperature of his internal organs), approximately correlates with the power produced by the patient's organism in the state of rest, i.e., approximately 50W. The average value of the entire surface of a patient is about 7000cm². Therefore, in the simplest approximation, the supply of 0.003W is needed for 1cm² of the surface.

For example, if the heating strip 18A is made of stainless steel with the thickness of 0.05mm and specific resistivity of 0.7Ohm•mm²/m, then with the current of 6A and voltage of 2V the required temperature of the strip surface through which heat is dissipated will be about 41°C. Here, the width and length of the strip were considered, respectively, 40mm and 1m. In this case, the surface area of the strip through which heat is dissipated and transferred to the surface of the patient's body is 400cm², and the heat flow from 1cm² thereof is 0.03W. It is thus

evident that, in order to obtain a temperature of the patient's body of about 37°C, heat flow that reaches the surface of a patient's body should be reduced with respect to that generated by the heating strip 18A. This is implemented by the heat diffusing strip 18B, due to its high heat conductivity.

5 In the present example, the heat diffuser strip 18B is made of aluminum foil, with a thickness in the range 0.02-0.05mm, and with the surface area larger than that of the heating strip (no less than five times). This means that if the width of the heating strip 18A is about 40mm, then the width of the aluminum foil strip 18B is no less than 20mm. At least those surfaces of the strips that face each other are
10 coated with thin insulating layers, e.g., lacquer.

Due to the high heat conductivity of aluminum foil, heat dissipated by the heating strip 18A is uniformly distributed and transferred to the patient's body with the acceptable density of heat flow. Generally speaking, the density of heat flow reaching the patient's body should be such as not to cause overheating thereof
15 above the required temperature, which is 37°C in this specific example. As indicated above, this approach enables to reduce the temperature of surface of the heating strip by 3-4°C, while maintaining the desired temperature of the surface of the patient's body.

It should be noted that since the electric heating does not utilize liquid
20 transfer or gaseous transfer at all, it is a simple task to divide the entire heating element into several parts of equal dimensions and equal power, taking into account that the same power is required for heating both arms of a patient and for heating his leg, in accordance with their dimensions. Therefore, each element of the heating device may be a heater with the power of 12W, 6W being needed for each patient's
25 arm.

Turning back to Fig. 1, the power supply source 14 may be accumulator-based. In this case, it is sufficient to connect the aluminum strip (heat diffuser) in series with the heating strip, to solve the problem of the influence of the electric heater on electronics in the vicinity of the device.

The above can be explained as follows. First, the use of an accumulator as a power supply source eliminates the creation of an electromagnetic field, due to the absence of the alternating current component. The accumulator provides direct voltage output in which the alternating component is absent, which results in the absence of electric current oscillations, and thereby the absence of the electromagnetic field. As for a magnetic field created by the electric current passing through the heating strip, it can be reduced to zero by connecting the aluminum strip in series with the heating strip due to the mutually symmetrical accommodation of both strips and opposite directions of the currents in these strips.

5 absence of electric current oscillations, and thereby the absence of the electromagnetic field. As for a magnetic field created by the electric current passing through the heating strip, it can be reduced to zero by connecting the aluminum strip in series with the heating strip due to the mutually symmetrical accommodation of both strips and opposite directions of the currents in these strips.

10 As the resistivity of the aluminum strip is almost by order less than that of the heating strip, owing to its smaller specific resistivity and higher width, the heat dissipated from the aluminum strip is negligible and does not affect the entire heat supply towards the patient's body.

Reference is made to Fig. 4, showing the main functional elements of the system 10 of Fig. 1. The power supply source utilizes an accumulator unit 20 including two batteries B_1 and B_2 , each selectively chargeable by a standard charging unit 22 typically including a step-down transformer (not shown). The charging unit 22 is interconnected between a power network and an analyzing unit 24, which operates to switch between the batteries B_1 and B_2 , so as to selectively connect one of them (which is charged) to the heating element 25. A connecting unit 26 operates to connect/disconnect the heating element 25 to the accumulator unit 20. A processing and managing unit 28 is provided being interconnected between the heating element 25 and the connecting unit 26, and being connected to an indication unit 30.

15 system 10 of Fig. 1. The power supply source utilizes an accumulator unit 20 including two batteries B_1 and B_2 , each selectively chargeable by a standard charging unit 22 typically including a step-down transformer (not shown). The charging unit 22 is interconnected between a power network and an analyzing unit 24, which operates to switch between the batteries B_1 and B_2 , so as to selectively connect one of them (which is charged) to the heating element 25. A connecting unit 26 operates to connect/disconnect the heating element 25 to the accumulator unit 20. A processing and managing unit 28 is provided being interconnected between the heating element 25 and the connecting unit 26, and being connected to an indication unit 30.

20 connect one of them (which is charged) to the heating element 25. A connecting unit 26 operates to connect/disconnect the heating element 25 to the accumulator unit 20. A processing and managing unit 28 is provided being interconnected between the heating element 25 and the connecting unit 26, and being connected to an indication unit 30.

25 The processing and managing unit 28 performs the following functions: it controls the operation of appropriately provided one or more temperature sensors (not shown) that generate data indicative of the current temperature of the patient's body; analyzes the current temperature of the patient's body; controls the operations of the switching and connecting units 24 and 26. The indication unit 30 provides

indication of the operational state of the other units, and the temperature of the patient's body.

When designing the above circuit, the following important operational requirements are considered:

- 5 A. The provision of complete electrical safety for both the patient and medical personnel;
- B. The continuous control of the temperature level of the patient's body;
- C. The control of breaking of the temperature sensor circuit associated with means involved in the anesthesia process and with the external temperature
10 sensors;
- D. The continuous control of the extent of discharging of the battery with the possibility of switching to a reserve battery;
- E. The reduction as much as possible in the signal-noise level with respect to other electronic equipment.

15 It should be noted that in the conventional systems of the kind specified, only the temperature of the patient's internal organs is determined. However, the temperature of the external surface of the patient's body in at least one location (but preferably 2 or 3 three locations) on the body should be measured, since the disturbance of the vascular system may occur.

20 When putting the system of the present invention into operation by pressing an ON/OFF button (not shown), indication that the system is connected to a power network is provided by any suitable means, for example, a lamp. Other suitable indicators, e.g., lamps, provide indication that the fuses of the primary coil of the step-down transformer are in good condition. The voltage of 220V is supplied to
25 the transformer, and the lowered alternating voltage of about 7V is provided on the secondary coil of the transformer. Alternating voltage is supplied from the secondary coil onto a diode bridge, and then onto a voltage stabilizer. As a result, an output DC voltage of about 6V is provided at the output of the charging unit 22. This voltage output is aimed at recharging the batteries, either battery B_1 or B_2 ,
30 depending on the extent of the battery discharge.

As to which battery should be put in operation and which one should be recharged, this is determined by the analyzing scheme in the analyzing unit 24. During the analyzing procedure, the unit 24 generates a signal indicative of the switching procedure, in response to which a transistor (not shown) in the processing and managing unit 28 is closed, which means that the current flow in the heating strip is halted, and an electrical circuit between the units 24 and 26 is disconnected. This is implemented by mechanical means, such as relay contacts. This having been done, that battery which is more discharged among the two, is connected to the charging unit 22 by switches (relay contacts), while the other battery is connected to the circuit line operating for heating. After the completeness of the process of switching between the batteries, control signals are sequentially generated in the processing and managing unit 28, so as to put the heating device into operation, namely, the relay contacts are closed and the transistor in the unit 28 is completely opened. Then, the unit 28 is completely put in operation.

As indicated above, the presence of the temperature sensors is considered. The processing and managing unit 28 continuously controls the magnitude of the temperature and controls the situation of accidentally breaking of the temperature sensors. Concurrently with this control, the indication unit 30 proves information about the temperature value exposed to an authorized person.

Following are several processes that may occur during the operation in an operating room:

1. The temperature of the patient's body exceeds the given value. In this case, a corresponding signal is generated in the processing and managing unit 28, so as to lock the transistor. Accordingly, the relay contacts are disconnected. The indication unit 30 provides a signal indicative of the fact that the heating process is halted. The unit 28 continues to control the decrease in the temperature of the patient's body, and upon detecting that the temperature is less than the defined threshold, generates corresponding signals so as to switch on the heating process (the relay contacts are closed and the transistor is opened). The indication unit 30 provides indication to the fact that the heating is turned on.

2. The temperature of the patient's body does not reach the given value, and an indication signal indicative of switching between the batteries is generated by the unit 30. In this case, the processing and managing unit 28 generates a sequence of signals aimed at disconnecting the heating element 25 from the battery, 5 and operates the analyzing unit 24 for switching between the batteries. The units 24 and 28 operate together so as to allow the switching process. After switching to the correct battery, the heating element is supplied with the required voltage so as to perform the heating process.

In the present example, the electrical conditions are as follows:

10 Electric voltage of about 220V is supplied to the accumulator unit 22 through screened wires with doubled electrical insulation. The fuses are mounted in two phases of the primary network of the transformer. Human access to the fuses without the use of a special tool is completely avoided. The transformer is of a down step torroidal kind, and the strengthened double insulation is provided 15 between its primary and secondary windings and between the primary winding of the magnetic core. There is no such moment in time when the heating element is in its operating position during the switching between the batteries. In other words, when the processing and managing unit 28 operates to provide switching between the batteries, the heating element 25 is previously disconnected and maintained in 20 this position during the entire re-switching process. i.e., the heating element is mechanically (and electrically) disconnected from the accumulator unit 20 and from the charging unit 22. Thus, only one, charged battery is always electrically connected to the heating element, while being at that time disconnected from the charging unit 22 (i.e., from the power network).

25 Thus, the present invention enables an as low as desired temperature gradient between the temperature of the surface of the heating conductor and that of a body to be heated. The provision of the heat diffusing conductor enables to provide the uniform distribution of heat flow directed towards the body, and to reduce the heat flow reaching the body. When required, the heat diffuser conductor

may be connected to the power source to compensate a magnetic field created in the vicinity of the heating conductor.

5 The thermal safety of the patient is guaranteed due to the continuous control of the temperature of the patient's body, as well as the continuous control of the state of the temperature sensors, with the provision of indication signals (audio and visual) and with necessarily disconnection of the electric heating element.

Those skilled in the art will readily appreciate that various modifications and changes can be applied to the preferred embodiment of the invention as hereinbefore exemplified without departing from its scope defined in and by the
10 appended claims. For example, any suitable materials other than those indicated in the above description can be used for manufacturing the heating conductor and the heat diffusing conductor, provided the specific resistivity of the heat diffusing conductor is substantially lower than that of the heating conductor, while its heat conductivity is high.

CLAIMS:

1. A heating device for surface heating of a body so as to maintain a required temperature of the body, the heating device comprising an electrical heating element and a power source for supplying a required voltage to the heating element,
5 wherein:
said heating element comprises first and second conductors made of materials with relatively high and low specific resistivities, respectively, as compared to each other, the second conductor material having high heat conductivity;
the second conductor is accommodated between the first conductor and the body
10 when in an operative position of the heating device, and at least said first conductor with relatively high specific resistivity is connected to said power source during the operation of the device, such that the first conductor is a heater and the second conductor is a heat diffuser, thereby providing an as low as desired temperature gradient between the surface temperature of the heating
15 conductor and said required temperature of the body.
2. The device according to Claim 1, wherein the first and second conductors are accommodated in parallel spaced-apart relationship along their length, and electric currents flow in the conductors in opposite directions.
3. The device according to Claim 2, wherein the first and second conductors
20 are electrically connected in series to each other with respect to said power source.
4. The device according to Claim 1, wherein the surface area of the second conductor is larger than the surface area of the first conductor.
5. The device according to Claim 4, wherein each of the first and second conductors is shaped like a strip.
- 25 6. The device according to Claim 5, wherein length, l , and width, b , of the first conductor satisfy the following relationships:

$$l \geq k \cdot U \cdot \sqrt{\frac{\delta}{\rho}} \qquad b \geq k \cdot l \cdot \sqrt{\frac{\rho}{\delta}}$$

wherein U is the voltage that falls on the first conductor; I is the current flowing through the conductor; ρ is the specific resistivity of the conductor material; δ is the thickness of the strip conductor; k is a coefficient depending on the body to be heated and said required temperature, so as to satisfy the condition that electric power supplied to the conductor is substantially equal with a heat power dissipated through the surface of the conductor.

7. The device according to Claim 1, wherein each of the first and second conductors is coated with a thin insulating layer.

8. The device according to Claim 7, wherein said thin insulating layer is lacquer.

9. The device according to Claim 1, wherein said required voltage is substantially low.

10. The device according to Claim 9, wherein said required voltage substantially does not exceed 12V.

11. The device according to Claim 1, wherein the first material has the specific resistivity in the range $0.3-1\text{Ohm}\cdot\text{mm}^2/\text{m}$.

12. The device according to Claim 1, wherein the second material has the specific resistivity in the range $0.015-0.03\text{Ohm}\cdot\text{mm}^2/\text{m}$.

13. The device according to Claim 12, wherein said second material is aluminum foil.

14. The device according to Claim 11, wherein said first material is transformer steel.

15. The device according to Claim 11, wherein said first material is stainless steel.

16. The device according to Claim 1, wherein said power source comprises an accumulator unit.

17. The device according to Claim 16, wherein said accumulator unit comprises at least two batteries, selectively operable by a switching unit, so as to connect a selective one of the batteries to the heating element.

18. The device according to Claim 17, wherein a charging unit is provided and selectively operable to charge that one of the batteries which is disconnected from the heating element.

19. The device according to Claim 17, wherein said selected one of the
5 batteries, while being connected to the heating element, is mechanically and electrically disconnected from a power network.

20. The device according to Claim 1, wherein said body to be heated is the patient's body undergoing treatment.

21. The device according to Claim 20, wherein at least said second conductor
10 of the heating element is accommodated inside a bed-sheet for covering the body to be heated.

22. The device according to Claim 20, wherein at least said second conductor of the heating element is accommodated inside a mattress underneath the body to be heated.

15 23. A heating device for surface heating of a patient's body in an operating room, the heating device comprising an electrical heating element and a power source coupled to the heating element for supplying a required voltage thereto, wherein

said heating element comprises first and second conductors made of materials
20 with relatively high and low specific resistivities, respectively, as compared to each other, the second conductor material having high heat conductivity;
the second conductor is accommodated between the first conductor and the body when in an operative position of the heating device, and at least said first conductor with relatively high specific resistivity is connected to said power
25 source during the operation of the device, such that the first conductor is a heater and the second conductor is a heat diffuser, thereby providing an as low as desired temperature gradient between the surface temperature of the heating conductor and said required temperature of the body.

24. The device according to Claim 23, wherein said heat diffuser is made of
30 aluminum foil.

25. The device according to Claim 23, wherein said power source comprises an accumulator unit.

26. The device according to Claim 25, wherein said accumulator unit, when being connected to the heating element is disconnected from a power network.

5 27. The device according to Claim 25, wherein said accumulator unit comprises at least two batteries, selectively operable by a switching unit, so as to connect a selective one of the batteries to the heating element.

28. The device according to Claim 27, wherein a charging unit is provided and selectively operable to charge the disconnected battery.

10 29. The device according to Claim 27, wherein said selected one of the batteries, while being connected to the heating element, is mechanically and electrically disconnected from a power network.

30. A heating system to be applied to a body for heating it up to a required temperature and maintaining this temperature, the system comprising a heating
15 device, a power source for supplying a required voltage thereto, and a control system, wherein

the heating element comprises first and second conductors made of materials with relatively high and low specific resistivities, respectively, as compared to each other, the second conductor material having high heat conductivity;

20 the second conductor is accommodated between the first conductor and the body when in an operative position of the heating device, and at least said first conductor with relatively high specific resistivity is connected to said power source during the operation of the device, such that the first conductor is a heater and the second conductor is a heat diffuser, thereby providing an as low as
25 desired temperature gradient between the surface temperature of the heating conductor and said required temperature of the body; and

the control system comprises at least one temperature sensor associated with the body to be heated, a processing and managing unit, and an indication unit, such as to provide continuous control of the temperature of the body and of the
30 operation of the temperature sensor and to provide indication thereof.

31. The system according to Claim 30, wherein
- the power source comprises an accumulator unit including at least two batteries, and a charging unit for selectively charging the batteries;
- s said control system comprises an analyzing unit for analyzing the extent of discharge of each of the batteries and selectively operating the charging device to charge a respective battery; and a switching unit for disconnecting mechanically and electrically the battery to be charged from the heating element, and the charged battery connected to the heating element from the charging device.



INVESTOR IN PEOPLE

Application No: GB 0007735.4
Claims searched: 1,3 at least

Examiner: John Cockitt
Date of search: 29 September 2000

Patents Act 1977 Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H5H [HAA2, HAA3, HAA7, HAA8, HAA9, HAAX1, HBA2]

Int Cl (Ed.7): H05B [3/34, 3/36, 3/38]

Other: ONLINE: EPODOC, WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2316848A	STRIX - see Cu heat diffuser in thermal contact with heater track	1,2,7,8 at least
X	GB2207030A	UNITED KINGDOM - see Al panel dispersing heat to avoid hot spots	1 at least
X	GB2104360A	MAAHS - see Cu heat diffuser 18 overlying heating conductor.	1,23,30 at least
X	GB0811992A	BRUCE - see Cu heat dispersion strip 3 overlying Cu-Ni heating resistance	1,2,4 at least
X	EP0110121A	FLABEG - see thermal/electrical strips overlying heating element	1,3 at least
X	JP070022159A	NIPPON - see heat dispersal plate 7 acting as a supply conductor.	1,3 at least

X Document indicating lack of novelty or inventive step

Y Document indicating lack of inventive step if combined with one or more other documents of same category.

& Member of the same patent family

A Document indicating technological background and/or state of the art.
P Document published on or after the declared priority date but before the filing date of this invention.

E Patent document published on or after, but with priority date earlier than, the filing date of this application.